UNIT 2 SUMMARY & REVIEW

Chapter 4 Chemical Bonding and Properties of Matter

Key ideas

- The three types of chemical bonding are ionic bonding, covalent bonding, and metallic bonding.
- Bonds form a continuum from equal sharing to minimal sharing of electrons. Bonds with a ΔEN from 1.7 to 3.3 are mostly ionic; with a ΔEN from 0.4 to 1.7 are polar covalent; and with a ΔEN from 0.0 to 0.4 are mostly covalent (or non-polar covalent).
- The electron-sea model visualizes a metal as a fairly ordered array of cations in a "sea" of freely moving electrons, with the positively charged ions all attracted to many of the electrons in the "sea" simultaneously.
- Metals and ionic compounds form crystals, but the structure of the crystals and the bonding between ions are different in ionic compounds, so their properties are different from those of metals.
- Valence bond (VB) theory proposes that a covalent bond forms when the atomic orbitals of two atoms overlap to share a common region in space, and a pair of electrons occupies that region of overlap.
- Molecular orbital (MO) theory proposes that when atomic orbitals overlap, they combine to form new orbitals called molecular orbitals, which have new shapes and energy levels and delocalized electrons.
- Hybrid orbitals are formed by the combination of two or more orbitals in the valence shell of an atom.
- In network solids, a large number of atoms are bonded together by a repeating network of covalent bonds.
- The structures of molecular compounds are much more varied than the structures of ionic compounds, in part because of the nature of covalent bonds.
- Different forces of attraction and repulsion determine the relative positions in space of atoms, bonding pairs of electrons, and lone pair of electrons, resulting in molecules with characteristic three-dimensional shapes. Chemists use different theories and models to predict these three-dimensional shapes.

- In a co-ordinate covalent bond, one atom contributes both electrons to the shared pair of electrons.
- In an expanded valence (expanded octet), a central atom has more than eight valence electrons.
- A resonance structure is a model in which two or more Lewis structures show the same relative position of atoms but different positions of electron pairs.
- VSEPR theory proposes that each electron group around an atom is positioned as far as possible from the others to minimize repulsions. An electron group consists of a single bond, double bond, triple bond, or lone pair. The result is a particular geometric arrangement of the electron groups.
- Electron-group arrangement refers to the way in which groups of valence electrons are positioned around a specific atom. Molecular shape refers to the relative positions of the atomic nuclei in an entire molecule.
- Intermolecular forces are forces of attraction and repulsion that act between molecules and influence the physical properties of solids and liquids.

Knowledge and Understanding

Select the letter of the best answer below.

1. Which of the following statements about electromagnetic radiation is false?

a. All forms of electromagnetic radiation travel at a speed of 3×10^8 m/s in a vacuum.

b. Radio waves and microwaves are found in the high-frequency region of the electromagnetic spectrum.

c. The frequency and the wavelength of all forms of electromagnetic waves are inversely proportional to each other.

d. The amplitude of an electromagnetic wave is related to the brightness or intensity of the wave.

e. The energy of a photon of electromagnetic radiation is directly proportional to the frequency.

2. Which sets of quantum numbers describe electrons in the same energy sublevel?

	n	l	m_l	m_s
i.	2	1	0	$-\frac{1}{2}$
ii.	2	1	−1	$+\frac{1}{2}$
iii.	3	1	−1	$+\frac{1}{2}$
iv.	2	2	−1	$+\frac{1}{2}$
v.	3	2	−1	$-\frac{1}{2}$

a. i, ii

b. iii, v

c. ii, iv

d. ii, iii

e. iv, v

3. Which of the following represents the orbital-shape quantum number?

a. n

b. m_l

c. p

d. l

e. m_s

4. Which of the following values can the magnetic quantum number have?

a. from 0 to n
b. $+\frac{1}{2}$ or $-\frac{1}{2}$
c. from 0 to $n-1$
d. from $-n$ to $+n$
e. from $-l$ to $+l$

5. Which quantities have similar patterns of increase or decrease across and down the periodic table?

i. atomic number
ii. atomic radius
iii. first ionization energy
iv. electron affinity
v. electronegativity

a. i and ii
b. i, iii, and iv
c. i and v
d. iii and iv
e. iii, iv, and v

6. Which of the following is not a property of metals?

a. low melting point
b. conducts electric current
c. ductile
d. hard
e. malleable

7. The molecule BF_3 is best represented as

a. an incomplete octet.
b. a resonance structure.
c. an ionic compound.
d. an expanded valence.
e. None of the above are correct.

8. VSEPR theory allows you to predict

a. the polarity of a simple molecule.
b. whether a compound is ionic or molecular.
c. the shape of a molecule around a central atom.
d. the Lewis structure.
e. the two-dimensional structure of a molecule.

For questions 9 to 15, choose from the answers below:

a. ionic solid
b. covalent network solid
c. metallic solid
d. molecular solid (polar molecules)
e. molecular solid (non-polar molecules)

9. The solid is composed of positive ions sharing electrons with neighbouring positive ions.

10. All of the particles in the solid are bonded together covalently.

11. Only dispersion forces of attraction exist between the particles in this solid.

12. The melting points are usually very low.

13. The solid is a good conductor only when melted.

14. The solid is extremely hard, not malleable, and a poor conductor of electric current.

15. The solid is often soluble in water but does not conduct electric current in solution.

Answer the questions below.

16. How is the Rutherford model of the atom similar to the Thomson model of the atom? In what ways are these two models different?

17. Although Bohr's model was unable to explain some of the characteristics of atoms, it marked a shift in the importance of understanding the inner workings of the atom to other areas of chemistry and physics.

a. What observations about atoms was Bohr's model able to explain?
b. How did Bohr's model solve the problem created by the theory of electromagnetic radiation that an orbiting electron should emit radiation and spiral into the nucleus?
c. What observations was the Bohr model not able to explain?

18. Explain why the atomic radii decrease across a period even though the atomic number increases?

19. Outline the steps to follow when filling orbitals to determine the electron configuration of an atom. Include the names of the principles involved in the process.

20. Answer the following with respect to electromagnetic radiation.

a. List two types that have a higher frequency than visible light.
b. Which colour in the visible spectrum is closest to the types that you listed in part (a)?
c. List two types that have a lower frequency than visible light.
d. What property of electromagnetic waves is common to all types?
e. Which colour has a longer wavelength: red or blue?

21. Use the terms *electronegativity* and *continuum* to classify chemical bonds as mostly covalent, polar covalent, and mostly ionic.

22. What information about an electron inside an atom does the second quantum number, l, provide?

23. List at least three of the four postulates on which Bohr based his model of the atom.

24. What is meant by the tempering of steel and how is it done?

25. Identify the physical or chemical properties that can be explained by the following characteristics of bonding:

a. delocalization of electrons in metallic bonds

b. formation of cations and anions in ionic bonding

c. covalent bonding throughout a solid, such as diamond

26. What properties of an ionic compound determine whether it is soluble in water?

27. What electrostatic forces are acting in a covalent bond?

28. Use VSEPR theory to identify the electron group arrangement (VSEPR shape), the molecular shape, and the bond angle of the following molecules whose central atoms have

a. 5 bonding pairs and 1 lone pair.

b. 4 bonding pairs and 1 lone pair.

c. 2 bonding pairs and 3 lone pairs.

d. 3 bonding pairs and 1 lone pair.

e. 4 bonding pairs and 2 lone pairs.

f. 4 bonding pairs and 0 lone pairs.

29. What evidence indicates that attractive forces exist among non-polar molecules?

30. What did each of the following Canadian scientists contribute to the better understanding of the structure and properties of matter?

a. Richard F.W. Bader of McMaster University

b. Robert J. LeRoy of the University of Waterloo

c. Ronald J. Gillespie of McMaster University

Thinking and Investigation

31. Use the periodic table to help you write the condensed electron configuration for the following elements and their most likely ion (if there is one):

a. boron

b. magnesium

c. sulfur

d. potassium

e. hydrogen

32. Using a periodic table, compare nitrogen and fluorine on the various properties given and choose

(a) if nitrogen has the larger (or more positive) value.

(b) if fluorine has the larger (or more positive) value.

(c) if they have the same value.

i. first quantum number, n, of the outermost electron

ii. atomic size

iii. first ionization energy

iv. second quantum number, l, of the outermost electron

v. electronegativity

33. Which elements are represented by the following electron configurations?

a. $1s^2 2s^2 2p^1$

b. $1s^2 2s^2 2p^5$

c. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

d. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

e. $1s^1$

f. $1s^2 2s^2 2p^6 3s^2 3p^6$

34. Use a basic periodic table that does not contain electron configurations to determine which element is defined by $[He]2s^2 2p^2$.

35. Use a basic periodic table that does not contain electron configurations to determine which element is defined by $[Kr]5s^2 4d^{10} 5p^5$.

36. Consider the pattern of the periodic table.

a. Find out which group element 119 would be in.

b. Predict the following information about element 119:

i. condensed electron configuration

ii. set of quantum numbers for the last electron to be added to it

iii. physical state at room temperature

iv. chemical property

Use the table below to answer questions 37 through 40:

Compound	Melting Point (°C)	Solubility in Water (g/g H_2O, 25°C)
NaF	988	0.042
NaCl	801	0.357
NaBr	755	1.16
NaI	651	1.84

37. Explain why it makes sense that the melting point decreases from NaF to NaI.

38. Explain why it makes sense that the solubility increases from NaF to NaI.

39. Cesium fluoride has a melting point of 682°C and a solubility of 3.67 g/g H_2O at 25°C. Explain why it makes sense that these values differ from the corresponding values for NaF.

40. Use VSEPR theory to predict the molecular shape for $C_2H_2Cl_2(\ell)$ and draw a three-dimensional diagram for the compound. Indicate the polarity of the bonds on your diagram. Based on your sketch, is the molecule polar or non-polar? In reality, this molecule may be either polar or non-polar. Draw an additional diagram to illustrate this point.

41. Use the periodic table to help you draw the orbital diagram (for the valence shell only) for the elements listed below, as well as their most likely ions (if there is one).

a. boron
b. magnesium
c. sulfur
d. potassium
e. hydrogen

42. Which elements in the second period of the periodic table have paired electrons in their valence shell, according to

a. their Lewis dot diagrams?
b. the aufbau principle?

43. Classify the following bonds as mostly ionic, polar covalent, or mostly covalent (non-polar covalent) by looking at the location of the elements on the periodic table. Check your classifications by calculating ΔEN for each pair.

a. Mg—S
b. C—C
c. P—O
d. Na—F

44. An unknown compound is a white solid at room temperature. It does not dissolve in water, cannot conduct an electric current in any state, and melts readily, even when heated gently.

a. What type of solid is it likely to be? Explain your answer.
b. Think of one common household substance that fits the description of the unknown compound.

45. Use VSEPR theory and Lewis structures to predict the number of bonding pairs and lone pairs around the central atom so that you can identify the e^- group arrangement, molecular shape, and bond angle for the following molecules and ions:

a. SnF_4
b. H_3O^+
c. AsF_5
d. ICl_2^-

46. Which compound in each of the following pairs has the higher boiling point? Explain your choice in each case.

a. H_2S or H_2O
b. SCl_4 or $SiCl_4$
c. propane (C_3H_8) or octane (C_8H_{18})

47. Compare and contrast the structures and physical properties of the covalent compounds propanol (C_3H_7OH), named for the alcohol group, —OH, attached to the carbon chain, and propanal (C_3H_6O), named for the carbonyl group, —C=O, at one end of the molecule.

Communication

48. Draw electron density maps for the following orbitals: 1*s*, 2*s*, 2*p*, 3*s*, 3*p*, all of the 2*p* orbitals together. In each case, try to ensure that the orbitals get larger from each energy level to the next energy level.

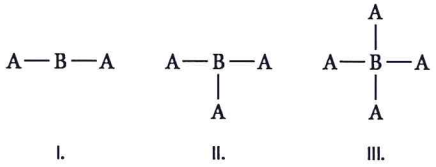
49. Analyze the molecules of ammonia, $NH_3(g)$, and ethanal, $CH_3CHO(\ell)$, according to the following directions:

a. Draw Lewis structures for the two molecules.
b. Analyze the Lewis structures according to VSEPR theory to determine the electron group arrangements and molecular shapes. For ethanal, consider the shape around the formyl carbon atom only. Explain, in writing and using diagrams, how your Lewis structures led to the electron group arrangements and molecular shapes.
c. Determine whether the molecules are polar or non-polar. Use arrows on your diagrams to indicate any polar bonds; if present, explain why polar bonds result in a polar molecule.

50. Draw a three-way Venn diagram to show the similarities and differences among polar covalent bonds, co-ordinate covalent bonds, and mostly (non-polar) covalent bonds.

51. Draw all of the resonance (Lewis) structures for SO_3.

52. What is the molecular shape of each molecule below?



Assume the following:

a. Each one has no lone pairs.
b. Each one has one lone pair.
c. Each one has two lone pairs.

Arrange your answer in a graphic organizer.

53. Use a table to summarize the distinguishing properties of ionic, covalent, metallic, and molecular (separate polar from non-polar) solids, including unit particle, type of attractions between particles, relative melting point, electrical conductivity (in solid, liquid, dissolved states), solubility (particular types of solvents), relative hardness/brittleness, and common examples.